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DESTROYER ENGINEERED OPERATING CYCLE (DDEOC)

LEVEL

System Maintenance Analysis

DDG-37 CLASS
SALT WATER CIRCULATING SYSTEM

SMA 37-106-256

REVIEW OF EXPERIENCE

July 1978

Prepared for
Director, Escort and Cruiser
Ship Logistic Division
Naval Sea Systems Command
Washington, D. C.
under Contract N00024-78-C-4062

ARINC RESEARCH CORPORATION

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This ~~Report, the~~ Review of Experience, documents the historical maintenance experience for the DDG-37 Class Salt Water Circulating system, presents an analysis of the problems encountered, and recommends actions to improve system material condition. It has been developed for NAVSEA 93 4X, the sponsor of the Destroyer Engineered Operationg Cycle (DDEOC) Program, under Navy Contract Nooo24-78-C-4062.

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SYSTEM MAINTENANCE ANALYSIS
DDG-37 CLASS
SALT WATER CIRCULATING SYSTEM

SMA 37-106-256

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FOREWORD

This report, the Review of Experience, documents the historical maintenance experience for the DDG-37 Class Salt Water Circulating System, presents an analysis of the problems encountered, and recommends actions to improve system material condition. It has been developed for NAVSEA 934X, the sponsor of the Destroyer Engineered Operating Cycle (DDEOC) Program, under Navy Contract N00024-78-C-4062.

SUMMARY

The goal of the Destroyer Engineered Operating Cycle (DDEOC) Program is to effect an early improvement in the material condition of ships, at an acceptable cost, while maintaining or increasing their operational availability during an extended operating cycle. In support of this goal, System Maintenance Analyses (SMAs) are being conducted for selected systems and subsystems of designated surface combatants. The principal element of an SMA is the Review of Experience (ROE). This report documents the ROE for the DDG-37 Class Salt Water Circulating System.

The ROE is an analysis of existing and anticipated problems that affect the operational performance or maintenance programs of a ship's system. The ROE report serves as a vehicle for assessing the significance and consequences of identified maintenance problems. It also presents specific recommendations and a system maintenance policy for preventing or reducing the effect of problem occurrence, while improving material condition and maintaining or increasing system availability throughout an extended operating cycle.

The Salt Water Circulating System ROE included an analysis of all available maintenance data sources. The documented maintenance experience of the system was reviewed through analysis of Maintenance Data System (MDS) data, Casualty Reports (CASREPs), and system overhaul records. Initial findings from these sources were correlated with Planned Maintenance System (PMS) requirements, system alterations, and system technical manuals to identify maintenance problems. Ship surveys were conducted, and discussions were held with appropriate technical codes to validate identified problems, identify undocumented maintenance problems, and determine the status of current and planned actions affecting the system. All findings were evaluated, and appropriate conclusions were developed. Recommendations were then formulated to (1) implement existing and newly defined corrective actions, (2) minimize the occurrence of identified problems and their impact on the extended operating cycle, and (3) identify the maintenance required throughout the operating cycle.

[illegible] The following are [illegible]

The major findings and conclusions resulting from the ~~Review of~~ ROE ~~Experience~~ for the Salt Water Circulating System are summarized as follows:

- Comprehensive overhaul will be necessary for the main salt water circulating pump turbine and auxiliary circulating pumps during Baseline Overhaul. [illegible]

- With the exception of the auxiliary circulating pumps, the system components will require restorative maintenance during the operating cycle but not at fixed intervals. The auxiliary circulating pumps should be overhauled at five-year intervals, and all other components should be maintained by using a "fix-when-fail" maintenance philosophy.

- An on-condition maintenance philosophy is not appropriate for components of this system; therefore, development of material condition assessment parameters and procedures for components of this system is not required.

- The strainer protecting the turbogenerator lube oil cooler is not properly sized, which allows debris to pass through and clog the oil cooler tubes.

Reliable operation of the Salt Water Circulating System can be expected during the Engineered Operating Cycle if several recommended changes are implemented in the following areas:

- Baseline Overhaul (BOH) Requirements
- Intra-Cycle Maintenance Requirements
- Follow-On Regular Overhaul (ROH) Requirements
- Reliability and Maintainability Improvements
- Planned Maintenance System Changes
- Industrial Facility Improvements
- Intermediate Maintenance Activity (IMA) Improvements
- Integrated Logistics Support (ILS) Requirements

Table S-1 summarizes all recommendations resulting from this Review of Experience.

Table S-1. SUMMARY OF ROH RECOMMENDATIONS FOR THE DDG-37 CLASS SALT WATER CIRCULATING SYSTEM

Component	Recommendation
Baseline Overhaul Requirements	
Main Circulating Pump Turbine	Overhaul in accordance with TRS 256-086-601.
Main S.W. Circulating Pump	Overhaul as shown to be necessary by POT&I or ship's CSMP.
Auxiliary Circulating Pump	Overhaul in accordance with TRS 256-086-600 or TRS 256-086-619.
Auxiliary Circulating Pump Motor	Overhaul as shown to be necessary by POT&I or ship's CSMP.
Auxiliary Circulating Pump Motor Controllers	Overhaul as shown to be necessary by POT&I or ship's CSMP.
Expansion Joints	Replace if more than five years old or if inspection shows replacement to be necessary.
Intra-Cycle Maintenance Requirements	
All Equipments of the Salt Water Circulating System	Accomplish PMS requirements as modified by the recommendations of this report.
Auxiliary Circulating Pump	Overhaul at five-year intervals.
Follow-On ROH Requirements	
Main Circulating Pump Turbine	Overhaul as shown to be necessary by POT&I or ship's CSMP.
Main Circulating Pump	Repair or overhaul as shown to be necessary by POT&I or ship's CSMP.
Reliability and Maintainability Improvements	
Auxiliary Circulating Pump	Overhaul at five-year intervals.
Duplex Strainer	Develop a ShipAlt to replace the existing duplex strainer with an appropriately sized unit.
Planned Maintenance System Changes	
Main Circulating Pump	Change the periodicity of the requirement to back-flush the lube oil cooler from monthly to quarterly on MIP E-5/59-A6, MRC 94 D37F N Add a note to perform the cyclical open-and-inspect requirement of the pump prior to the ship's regular overhaul on MIP E-5/59-A6, MRC 66-K32G N. Change the periodicity of the requirement to inspect the carbon packing and gear casing from cyclical to 36 months on MIP E-5/59-A6, MRC 65 H16V N. Change the periodicity of the requirement to inspect the reduction gears from cyclical to 36 months. Add a note that reduction gear maintenance should be performed by an industrial activity on MIP E-5/59-A6, MRC 65 H16W N.
Auxiliary Circulating Pump	Delete the annual open-and-inspect requirement for MIP E-17/296-21, MRC 21 A14V A.
Industrial Facility Improvements -- None	
IMA Improvements -- None	
Intergrated Logistic Support (ILS) Requirements	
Centrifugal Pumps and Motors	Provide Ship's Force with a suitable Centrifugal Pump Repair Manual.* Provide suitable ball-bearing heater ovens.*

*These recommendations were originally made in the DDG-37 Class Firemain and Auxiliary Machinery Cooling Water Systems SMA (SMA 37-201-521). Detailed rationale for these recommendations are contained in the referenced report, ARINC Research Publication 1652-03-15-1752.

CONTENTS

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

In support of the Destroyer Engineered Operating Cycle (DDEOC) Program sponsored by NAVSEA 934X, System Maintenance Analyses (SMAs) are being conducted on selected systems and subsystems of program-designated surface combatants. The principal element of an SMA is the Review of Experience (ROE). This report documents the ROE for the DDG-37 Class Salt Water Circulating System, which was selected for analysis because equipments of this system are on the DDG-37 Class Maintenance Critical Equipment List.

1.2 PURPOSE AND SCOPE

The ROE is an analysis of existing and anticipated problems that affect the operational performance or maintenance programs of a ship's system. The ROE report serves as a vehicle for assessing the significance and consequences of identified maintenance problems. It also recommends specific actions and a system maintenance policy directed toward preventing or reducing the effect of maintenance problem occurrence, while improving material condition and maintaining or increasing system availability throughout an extended operating cycle.

The analysis of the DDG-37 Class Salt Water Circulating System was concerned with only those system components that had been installed or were on board ship as of the fourth quarter of Fiscal Year 1977. The analysis used all available documented data sources from which system maintenance problems could be identified and studied. These data were obtained from the Maintenance Data System (MDS), Casualty Reports (CASREPs), system overhaul records, Planned Maintenance System (PMS) requirements, system alteration documentation, and system technical manuals. Sources of undocumented data employed in this analysis included discussions with Ship's Force and other cognizant technical personnel.

1.3 SYSTEM FUNCTION AND DESCRIPTION

The DDG-37 Class Salt Water Circulating System supplies cooling water to the main and auxiliary condensers, main lube oil coolers, and turbogenerator lube oil and air coolers.

The main Salt Water Circulating System consists of two identical turbine-driven salt water circulating pumps, two scoop injection systems, and associated valves and piping. One turbine-driven pump and one scoop injection system are associated with each main condenser. Water is provided to the main condenser and main lube oil cooler by either the pump or the scoop injection system. The scoop injection system provides cooling water at forward speeds over 12 knots. For speeds less than 12 knots and for all astern operations, cooling water is provided by the turbine-driven pump. Nonreturn or check valves prevent the reverse flow of water through these components. The turbine-driven pump has an additional damage control function in that it can, if required, take suction from the engine room bilge and assist in dewatering the space. The condenser and lube oil cooler are both isolated from the piping by expansion joints. Associated salt water piping and valves, including relief valves, and the turbine throttle valve constitute the remainder of the system.

Each DDG-37 Class ship has two functionally and schematically identical auxiliary salt water circulating systems in each engine room. Each system, including a motor, a close-coupled circulating pump, and a motor starter, is associated with a specific turbogenerator. The motor-driven pump supplies sea water to the associated turbogenerator condenser, lube oil cooler, and generator air cooler. The water supplied to the lube oil cooler passes through an inlet duplex strainer and the water to the air cooler passes through an inlet orifice. Associated piping and valves, including relief valves, constitute the remainder of the system (see Appendix A for a listing of system components).

1.4 REPORT FORMAT

The remaining chapters of this report describe the analysis approach utilized (Chapter Two), briefly define significant system maintenance problems encountered and discuss potential problem solutions (Chapter Three), and summarize conclusions and recommendations derived from the analysis (Chapter Four). Specific analyses and evaluations supporting the results of this effort are included as appendixes to this report. A selected list of references precedes the appendixes.

CHAPTER TWO

APPROACH

This chapter describes the approach taken to the performance of the ROE for the Salt Water Circulating System. Primary data sources were identified in Section 1.2. These data were used to identify, define, and analyze maintenance problems that will significantly affect the system's maintenance program. A recommended course of action relative to the maintenance program was formulated on the basis of the analysis results.

The analysis was initiated at the component level at which Allowance Parts List (APL) numbers are assigned. Major steps of the analysis were as follows:

- Compiling relevant documented and undocumented maintenance history data
- Analyzing these data to identify and define maintenance problems expected to have a significant impact on system maintenance
- Recommending a specific course of action for solution of system maintenance problems

Each of these activities is described in the following sections.

2.1 DATA COMPILATION

The analysis began with the compilation of comprehensive data on the maintenance history of the system. The data file consisted of four key elements: an MDS data bank, a CASREP narrative summary, a system overhaul experience summary, and a system ShipAlt summary. A library of appropriate technical manuals, bulletins, and related documents was also assembled. All MDS data reported for the DDG-37 Class from 1 January 1970 through 30 September 1977 were screened for information pertinent to the system. Overhaul information was obtained from authorized Ship Alteration and Repair Packages (SARPs) for the DDG-37 Class.

2.2 MAINTENANCE PROBLEM DEFINITION

Potential maintenance problems associated with the system and its components were identified by a screening process employing data obtained from the above-described sources as well as from ship surveys, discussions with Navy technical personnel, and, when appropriate, NAVSEA special-interest programs.

MDS data constituted the initial and primary source of information used in the screening process. The resulting data base includes all part and labor records, as well as narrative material, describing maintenance actions reported against system components. Maintenance actions are represented by Job Control Numbers (JCNs). Those JCNs reporting completed or deferred PMS actions or actions not relevant to corrective maintenance were excluded from further analysis. The purpose of the first step in the screening process was to identify the maintenance actions that had been reported against components of the system under investigation.

Computer-assisted analysis was next employed to quantify the man-hour and part-expenditure burdens incurred for each component, not only for the selected components individually but also, as appropriate, for each generic class of components. Individual components or component classes that had contributed significantly to the system's maintenance burden were selected for analysis if they had generated a significant number of CASREPs or if other sources of information (e.g., ship surveys or overhaul experience) disclosed significant concern regarding maintenance problems or the maintenance programs for the components.

Detailed analysis of the selected components was directed toward defining each maintenance problem in terms of several specific factors: the effect of the problem on the component and system, the interval between occurrences of the problem, the redundancy of the affected component within the system, the criticality of the component to the system, the resources required to perform the maintenance necessary to correct the problem, and the expected component or system downtime.

2.3 ANALYSIS OF COMPONENT MAINTENANCE PROBLEMS AND DEFINITION OF SOLUTIONS

Once the component maintenance problems and their causes were identified, solutions were sought by examining each problem in relation to the extent to which it is recognized and its susceptibility to established types of corrective action. These analysis criteria can be expressed in the following questions:

- Is the problem known to the Navy technical community and has a solution been proposed or established?
- Will a design change reduce or eliminate the problem?

- Is the problem PMS-related? Can the problem be reduced or eliminated by changes to PMS? (These changes might include adding or deleting requirements, changing requirement frequency, or developing material condition assessment tests and procedures.)

- Can the problem be reduced or eliminated by improving the Ship's Force, Intermediate Maintenance Activity (IMA), or depot-level capabilities?

- Can the problem be reduced or eliminated by periodically performing restorative maintenance? Should this be accomplished at a Selected Restricted Availability (SRA) by Ship's Force, IMA, or depot-level facilities?

- Is the run-to-failure concept a viable maintenance strategy for the associated equipment?

An affirmative answer to any question resulted in analysis of the effects of the solution and in an estimate, when possible, of the cost to implement the solution. A negative answer prompted the analyst to go to the next question. After all the questions were answered, the alternative near-term and long-term solutions were evaluated and the most acceptable alternatives defined and documented as recommendations. "Near-term" recommended solutions, as used in this report, are those that should be, and are likely to be, accomplished before completion of the initial DDG-37 Class Baseline Overhaul (BOH). "Long-term" recommended solutions are those that are not likely to be accomplished until some or all of the DDG-37 Class BOHs have been completed.

The historical overhaul experience for all installations of each selected component was then correlated with the recommended problem solutions. An evaluation was made to establish the BOH requirements for each selected component.

CHAPTER THREE

ANALYSIS RESULTS

3.1 OVERVIEW

Preliminary analysis of the MDS data resulted in the identification of eight system components and the principal valves of the main circulating system as warranting further analysis. The MDS maintenance burden data for these components is summarized in Table 3-1.

A review of part replacement histories identified those parts within the selected components requiring further analysis. Pertinent data for the parts are summarized in Table 3-2. CASREP analysis supported the MDS data analysis performed to define repetitive or significant maintenance actions. Appendix B summarizes the CASREPs reported against the Salt Water Circulating System and indicates the types of failures experienced. Ship surveys and discussions with Navy technical personnel confirmed the results of the analysis of the components and identified one additional problem with the auxiliary salt water circulating pump strainers not documented in MDS data.

The following system components were analyzed in detail because of significant intra-cycle maintenance experience:

- Main Circulating Pump Turbine (APL 057950046)
- Main Circulating Pump (APL 016020490)
- Auxiliary Circulating Pump (APL 016050209 and APL 016120387)
- Auxiliary Circulating Pump Motor (APL 175503584, APL 174752378, and APL 174180291)
- Salt Water Strainer (APL 755170019)

In addition, expansion joints were analyzed with respect to Baseline Overhaul requirements because the NAVSHIPS Technical Manual requires that they be renewed after ten years of service.

Although the maintenance history for the entire system was reviewed, no significant recurring problems with the exhaust relief valve or the major valves of the system were revealed. Therefore, they are not discussed in this report.

Table 3-2. MAINTENANCE BURDEN SUMMARY FOR DDG-37 CLASS SALT WATER CIRCULATING SYSTEM COMPONENTS*

APL	Nomenclature	Applicable Ships	Components per Ship	Total Component Population	Total Ship Operating Time (Ship-Years)	Ships Reported	JCNs	Ship's Force Man-Hours	IMA Man-Hours	Total Man-Hours	Parts Cost (Dollars)	Average Man-Hours/ Component Operating Year
Main Salt Water Circulating System												
057950046	Main Circ Pump Turbine	10	2	20	58.8	10	125	1650	860	2520	23000	21.4
882117275	Exhaust Relief Valve	10	2	20	58.8	10	18	90	270	360	660	3.1
016020490	Main Circ Pump	10	2	20	58.8	10	75	740	180	920	5370	7.8
Various	Major Valves**	10	12	120	58.8	10	35	230	650	880	980	1.2
						Subtotal	253	2710	1960	4680	30010	
Auxiliary Salt Water Circulating System+												
016050209	Auxiliary Circ Pump	2	4	8	12.6	2	21	720	410	1130	4610	22.4
016120387	Auxiliary Circ Pump	7	4	28	29.8	7	75	1620	950	2570	28920	21.6
175503584	Motor	7	4	28	29.8	7	25	170	240	410	1480	3.4
174752378	Motor	1	4	4	6.2	1	6	20	0	20	190	0.8
174180291	Motor	1	4	4	6.3	1	3	180	0	180	370	7.1
						Subtotal	130	2710	1600	4310	35570	
						Totals	383	5420	3560	8990	65580	
						Total For All System APLs	597	7080	5270	12350	79860	
						Percent of Total Accounted For By Selected APLs	65	77	68	73	82	

*JCNs reporting the accomplishment or deferral of a routine PMS action or not relating to component maintenance are not included in this table.
**Scoop injection, pump suction, bilge suction, scoop flapper, pump flapper, and main overboard valves.
+Maintenance data are not available on DDG-41 because the ship did not complete its modernization prior to the end of the data period.

Table 3-2. PARTS USAGE SUMMARY FOR SELECTED COMPONENTS OF DDG-37 CLASS SALT WATER CIRCULATING SYSTEM

Part Identification		Cost per Unit (Dollars)	Quantity per Component	Total Part Population	Number Replaced	Ratio (×100) of Parts Replaced to Total Population	Number of Ships Reported
NIIN	Nomenclature						
MAIN CIRCULATING PUMP TURBINE (APL 057950046)							
High Speed Pinion							
9Z 3110-00-679-4129	Bearing, Ball Annular	39.00	1	20	10	50	7
9Z 3110-00-679-4170	Bearing, Ball, Duplex Pair	105.04	1	20	11	55	7
9Z 3110-00-679-4296	Bearing, Roller, Cyl.	46.18	1	20	7	35	4
1H 2825-00-659-9910	Pinion	1761.76	1	20	1	5	1
Intermediate Speed Pinion							
9Z 3110-00-227-2441	Bearing, Roller, Tapered	13.83	2	40	11	28	4
Low Speed Pinion							
9Z 3110-00-100-5614	Bearing, Roller, Tapered	72.46	1	20	6	30	4
9Z 3110-00-227-4095	Bearing, Roller, Tapered	80.08	1	20	5	25	3
Governor							
1H 2825-00-659-9912	Stem, Gov. Valve	160.00	1	20	25	125	8
1H 2825-00-911-9?47	Rod and Piston	338.00	1	20	4	20	3
1H 2825-00-659-9915	Guide Valve, Gov. Valve	652.00	1	20	5	25	4
9Z 3120-00-540-3270	Bushing, Sleeve	3.01	2	40	13	32	5
1H 2825-00-659-9914	Disk, Valve, Metallic	854.00	1	20	6	30	5
9Z 3110-00-227-4718	Ball Bearing	0.26	1	20	17	85	6
9Z 3110-00-555-5226	Bearing, Ball, Annular	1.00	1	20	6	30	4
9Z 3110-00-902-1641	Bearing, Roller, Needle	1.21	4	80	21	26	4
1H 2825-00-575-6068	Needle Valve	175.00	1	20	8	40	5
1H 2825-00-660-1033	Spring, Helical	1.18	1	20	3	15	3
Other							
1H 2825-00-572-0954	Seal Assembly	8.40	4	80	53	66	5
1H 3020-00-585-1632	Gear, Helical	143.54	1	20	3	15	3
1H 6685-00-244-1830	Gauge, Pressure	4.72	1	20	8	40	3
MAIN SALT WATER CIRCULATING PUMP, APL 016020490							
9Z 3120-00-288-1770	Bearing, Sleeve	13.00	1	20	4	20	3
9C 4320-00-339-2708	Bearing, Sleeve	500.32	1	20	6	30	3

(continued)

Table 3-2. (continued)

Part Identification		Cost per Unit (Dollars)	Quantity per Component	Total Part Population	Number Replaced	Ratio (x100) of Parts Replaced to Total Population	Number of Ships Reported
NIIN	Nomenclature						
AUXILIARY SALT WATER CIRCULATING PUMP (APL 016050209)							
9C 4320-00-882-7667	Impeller Wearing Ring	37.61	2	16	13	81	2
9C 4320-00-882-7668	Casing Wearing Ring	63.68	2	16	10	62	2
9C 4320-00-369-7718	Impeller	917.84	1	8	5	62	2
9C 4320-00-876-6749	Shaft Sleeve	178.88	1	8	7	88	2
AUXILIARY SALT WATER CIRCULATING PUMP (APL 016120387)							
9C 4320-00-540-2540	Impeller Wearing Ring	20.82	2	56	66	118	7
9C 4320-00-540-2535	Casing Wearing Ring	29.29	2	56	73	130	7
9C 4320-00-257-0429	Impeller	1115.97	1	28	18	64	5
9C 4320-00-336-5356	Shaft Sleeve	102.96	1	28	46	164	7
9C 4330-00-097-5913	Deflector	18.40	1	28	16	57	6
9C 4320-00-243-9922	Lantern Ring	106.08	1	28	11	39	5
Motor (APL 175503584)							
9Z 3110-00-554-5655	Bearing, Ball, Annular	17.37	1	28	19	68	7
9Z 3110-00-155-6226*	Bearing, Ball, Annular	6.29	1	28	21	93	7
9Z 3110-00-554-5656*	Bearing, Ball, Annular	14.56	-	-	5		
Motor (APL 174752378)							
9Z 3110-00-518-6868	Bearing, Ball, Annular	17.48	1	4	3	75	1
9Z 3110-00-158-8271	Bearing, Ball, Annular	9.88	1	4	3	75	1
Motor (APL 174180291)							
9Z 3110-00-155-6230	Bearing, Ball, Annular	17.93	1	4	0	-	0
9Z 3110-00-554-3359	Bearing, Ball, Annular	8.55	1	4	0	-	0

*Substitutes.

3.2 MAIN CIRCULATING PUMP TURBINE (APL 057950046)

3.2.1 Background

The Main Circulating Pump Turbine consists of a single-stage, radial flow, multi-impulse-type steam turbine and a single helical-type double reduction gear. The turbine casing is vertically mounted on the reduction gear and the turbine rotor is rigidly connected to, and supported by, the reduction-gear high-speed pinion. The entire unit is vertically mounted on the main circulating water pump and the pump rotor is rigidly attached to the reduction gear output shaft. The reduction gear absorbs the thrust loading of the pump rotor.

The turbine is manufactured by the Whiton Division of the Terry Steam Turbine Company and the reduction gear by the Falk Gear Company.

3.2.2 Discussion

The major contributors to the maintenance burden of the main circulating pump turbine are the governor mechanism and the reduction gear. Table 3-3 breaks out the data into four categories: reduction gear, governor, turbine, and other data. The table shows that the governor is responsible for approximately 8.8 man-hours per component operating year (COY). The average maintenance burden of the reduction gear, when the DDG-38 data are excluded, is 2.5 man-hours per COY. These burdens are not considered excessive. Five CASREPs have been reported on the main circulating pump turbine during the data period. Of these, three were associated with failures of the reduction gears.

Table 3-3. ALLOCATION OF MAINTENANCE BURDEN ON MAIN CIRCULATING PUMP TURBINE* (APL 057950046)

Component	JCNs	Man-Hours			Component Operating Years (COY)	Man-Hours per COY
		Ship's Force	IMA	Total		
Reduction Gear**	28	637	181	818	117.6	7.0
Reduction Gear Minus DDG-38	25	157	111	268	106.6	2.5
Governor**	42	577	463	1,040	117.6	8.8
Turbine, Including Shaft Seal**	11	245	50	295	117.6	2.5
Other and Not Identifiable**	44	197	164	361	117.6	3.1

*Numbers do not equal those in Table 3-1 because of rounding.
**The sum of these entries represents the total maintenance burden of the reduction gears.

Very few actions were reported against the turbine, as evidenced by the total of only eleven JCNs reporting a total of 295 man-hours. Further, 88 percent of all Ship's Force man-hours were used in four maintenace actions, and all of the reported IMA man-hours were used in one of these four actions.

The main circulating pump turbine governor and reduction gears are discussed in the following sections. A discussion of changes to PMS follows those sections.

Governor

The governor system is designed to operate the turbine at a constant speed. It has three principal components: a mechanical flyweight assembly, a pilot valve, and a steam admission valve. The maintenance of this system has consisted of governor component overhaul and the replacement of parts subject to wear in each of the three components.

During the data period, 42 JCNs reporting 1040 man-hours or 8.8 man-hours per component operating year (COY) have been reported against the governor. The man-hours per action are quite high: 1040/42 = 24.8 man-hours per action, indicating that when maintenance was needed, a substantial amount of work was required to accomplish the repairs. Discussions with Ship's Force personnel indicated that corrective maintenance of the governor is normally within the capability of either the Ship's Force or IMA personnel.

Table 3-2 indicates that only two parts had significant part replacement ratios. The highest replacement ratio (125 percent) was for the governor valve stem (NSN 1H 2825-00-659-9912). This part mechanically links the pilot valve to the steam admission valve. It is particularly vulnerable to damage because of its exposed location and the need to manually move the valve stem, through an attached lever, when starting the turbine. The replacement rate of one per 4.7 COY is not considered excessive.

The ball bearing (NSN 9Z 3110-00-227-4718), with an 85 percent replacement ratio, is a single ball that acts as the lube oil pump relief valve disc. It is not considered maintenance-significant.

The low number of JCNs reported, the low man-hours usage, and the low parts replacement data tend to indicate that these components operate reliably. Reliable governor operation was confirmed in conversations with Ship's Force and cognizant technical personnel.

The governor should operate reliably throughout the intra-cycle period if it is overhauled at BOH and at each subsequent main circulating pump turbine overhaul. The historical maintenance data indicate that there will probably be some events during the intra-cycle period requiring maintenance on the governor; however, the exact nature and frequency of those events are not predictable. Ship's Force indicates that any such work will normally be within the capability of either Ship's Force or IMA personnel.

Reduction Gear

Sixteen of the 28 reported JCNs indicate major maintenance, a need for an overhaul, or parts requisitions (principally for bearings) that indicate major maintenance of the reduction gears. The data indicate that nine reduction gears had no major maintenance throughout the MDS data period (from 1 January 1970 through 30 September 1977); eight had one major maintenance action, and three had more than one.

A few of the major events referred to were entered in the MDS system as narrative requests in anticipation of the ship's overhaul. It is possible that other main circulating pump turbines were overhauled during modernization or ship regular overhauls during the data period. However, an examination of the DDG-37 repair profile and discussions with cognizant personnel revealed that the overhaul of these units was not usual.

The DDG-38 dominates the maintenance data for the reduction gear. It reported three major maintenance actions on one reduction gear within three years. The first of these actions required over 370 Ship's Force and IMA man-hours, and it was the largest single maintenance action on the reduction gear in terms of man-hours. The occurrence of three major maintenance events within a three-year period, the first involving major Ship's Force and IMA man-hours expenditure, indicates that Forces Afloat may not have the capability to adequately conduct major maintenance on reduction gears. The DDG-38 also experienced one major maintenance action requiring 148 man-hours on the reduction gear of its other turbine. This ship was responsible for four of the sixteen major maintenance actions reported against the reduction gears for the entire class.

In addition, the DDG-38 was responsible for about one half of the replacements of each pinion bearing in the reduction gear. Bearing replacement data with data for the DDG-38 shown separately appear in Table 3-4. Table 3-4 shows that the parts replacement ratio without the DDG-38 is 33 percent and 39 percent for the two ball bearings in the high-speed pinion and ranges from 11 percent to 17 percent for the other bearings in the reduction gear.

The MDS data indicate that in many of the cases of major maintenance, insufficient man-hours were reported to allow the conclusion that the Ship's Force or the IMA actually accomplished the work reported necessary. In gross terms, if all of the man-hours shown in the maintenance data, less DDG-38, were applied to the 12 remaining major actions, they would average only 268/12 = 22.3 man-hours/action. These are insufficient man-hours to accomplish major maintenance.* In addition, ship visits and CASREP and MDS narratives identified at least six specific instances where industrial assistance was used.

*It is necessary to remove the turbine from the pump and lift it vertically through an access hatch in main propulsion control and then to a safe work area before beginning to open the reduction gear casing.

Table 3-4. BEARING USAGE SUMMARY FOR MAIN CIRCULATING PUMP TURBINE (APL 057950046) REDUCTION GEAR BEARINGS OF DDG-37 CLASS SHIPS

NIIN	Nomenclature	Quantity per Component	DDG-38			Nine Ships		
			Total Part Population	Number Replaced	Ratio (×100) of Parts Replaced to Total Population	Total Part Population	Number Replaced	Ratio (×100) of Parts Replaced to Total Population
9Z 3110-00-679-4129	Bearing, Ball	1	2	4	200	18	6	33
9Z 3110-00-679-4170	Bearing, Ball, Duplex Pair	1	2	4	200	18	7	39
9Z 3110-00-679-4296	Bearing, Roller, Cycl.	1	2	4	200	18	3	17
9Z 3110-00-227]-2441	Bearing, Roller, Tapered	2	4	6	150	36	5	14
9Z 3110-00-100-5614	Bearing, Roller, Tapered	1	2	3	150	18	3	17
9Z 3110-00-227-4095	Bearing, Roller, Tapered	1	2	3	150	18	2	11

The DDG-37 Class SARP Planning Document calls for overhaul of the main circulating pump turbine in accordance with the applicable Technical Repair Standard (TRS) during baseline overhauls. On the basis that only a depot-level industrial facility can adequately undertake the removal, repair, balancing, and reinstallation of a steam turbine and gears with consistent success, a depot-level Class "B" Overhaul in accordance with the applicable TRS is recommended. The overhaul itself is recommended on the basis of the engineering judgment of what would be required to ensure reliable operation throughout the operating cycle.

It is concluded that the main circulating pump turbine can operate through the intra-cycle period without requiring major restorative maintenance provided it is overhauled at BOH. It is also concluded that if major maintenance is required, it should be undertaken by an industrial activity.

PMS

The total requirements for planned maintenance in a year, not including the cyclical open and inspect requirement, is greater than 62 man-hours per component for the main circulating pump and turbine. These requirements are contained on MIP E-005/059/A-6. Back flushing of the lube oil cooler (MRC 94 E87F N) takes twenty-four of those man-hours annually as it requires two man-hours per month. Cognizant technical personnel and Ship's Force reported that flushing was not required that frequently because there is apparently little fouling of the cooler within a month. Extending the flushing interval should have no adverse effect. Gradual deterioration in performance should be apparent to the Ship's Force in sufficient time to take corrective action before any damage occurs. Sudden deterioration in performance due to complete clogging would occur no matter what the frequency of cleaning.

It appears, then, that the frequency of this task could be changed to quarterly without any degradation in main circulating pump reliability or availability. This would reduce the annual PMS burden of this pump by 16 man-hours, or 26 percent.

Table 3-2 shows that the seal assembly (NSN 1H 2825-00-572-0954) had a replacement ratio of 66 percent over the data period, indicating the need for occasional removal. This assembly is a carbon packing ring that provides a steam-tight seal between the turbine casing and the shaft. The serious consequences of excessive steam leakage past the seal assembly on the turbine shaft (i.e., condensate leakage into the reduction gear casing and into the lube oil) make it advisable to retain the frequency of the PMS requirement to inspect carbon rings (MRC 65 H16V N) every 36 months.

An intra-cycle inspection of the gears should be accomplished by continuing the present PMS requirement for gear inspection (MRC 65 H16W N) at 36-month intervals. This task can be performed with a minimal man-hour expenditure and with minimal disruption to turbine availability.

3.2.3 Summary

The main circulating pump turbine will operate satisfactorily throughout an extended operating cycle if it is overhauled at BOH. The reduction gear should not experience major failure during the intra-cycle period if it is overhauled in accordance with the applicable TRS at BOH. Subsequent overhauls should be based on Pre-Overhaul Test and Inspection (POT&I) results. It is likely that the interval between successive overhauls of the main circulating pump turbine could safely be in excess of 60 months.

Major maintenance on the reduction gear or turbine required during the intra-cycle period should employ industrial assistance.

The governor may require overhaul of its components during the intra-cycle period. Any such work should be within the capability of Forces Afloat.

The recommended changes to PMS will significantly reduce the annual preventive maintenance burden with minimal effect on turbine reliability.

3.2.4 Recommendations

For the near term, the following actions are recommended:

- The main circulating pump turbine should have a Class "B" Overhaul at BOH in accordance with the applicable TRS.
- The frequency of the PMS requirement to back-flush the lube oil cooler (MRC 94 E 87F N) should be changed from monthly to quarterly.
- The frequency of the PMS requirement to inspect carbon packing and to inspect the turbine exterior (MRC 65 H16V N) should be changed from cyclical to 36 months.
- The frequency of the PMS requirement to inspect the reduction gears (MRC 65 H16W N) should be changed from cyclical to 36 months.

For the long term, the main circulating pump turbines should be overhauled during the follow-on Regular Overhaul as shown to be necessary by POT&I results and the ship's CSMP.

3.3 MAIN SALT WATER CIRCULATING PUMP (APL 016020490)

3.3.1 Background

The main salt water circulating pump is a vertically mounted, axial flow pump with internal, seawater lubricated sleeve bearings, housed in a split casing. It is driven by an attached st m turbine through reduction gears rigidly attached to the pump shaft. hrust load is carried by a thrust bearing located in the reduction a The pump is manufactured by the Warren Pump Company.

Each pump supplies cooling water to an associated main condenser and lube oil cooler. The pump is normally operated only when maneuvering at speeds under 12 knots and when going astern. As an emergency damage control measure, these pumps can take suction from the engine room bilge to aid in dewatering the space.

3.3.2 Discussion

As shown in Table 3-1, the main salt water circulating pumps have contributed 740 Ship's Force and 180 IMA man-hours to the total system maintenance burden over the data period for an average of 7.8 man-hours per COY.

The MDS data showed a total of only six actions on six different pumps on three ships, indicating a pump overhaul or a need for an overhaul. The low part replacement rate for pump components, shown in Table 3-2, also indicates that little maintenance was performed on these pumps. No CASREPs were reported against these pumps. These six actions occurred in pairs for each ship. All of these facts indicate that the overhauls took place as the opportunity arose for Ship's Force rather than as a result of failure. Four of the actions occurred in 1976 and 1977.

The DDG-37 ROH Repair Profile showed that these pumps have not historically been overhauled during a Regular Overhaul It is therefore probable that four pumps ran more than six years (from 1970 until 1976) without major maintenance and that twelve others have operated almost eight years (from 1970 through September 1977) without major maintenance. (The history of the pumps on DDG-41 is not included because of that ship's long modernization availability beginning in 1974 and extending to the end of the data period.)

The DDG-37 Class SARP Planning Document calls for these pumps to be overhauled in accordance with the applicable TRS during Baseline Overhaul. However, the basic reliability of these pumps suggests that they should be overhauled at BOH only if the ship's CSMP or POT&I call for it.

There is an existing cyclic PMS requirement (MIP E-5/59/A6, MRC 66 K32G N) to open and inspect the main circulating pump. It is recommended that this inspection be accomplished before the ship's Baseline and Regular Overhauls and that repair or overhaul be accomplished on the basis of the results of that inspection. The historically low reported maintenance burden of this pump indicates that if this is done, there would be a minimal need for maintenance during the intra-cycle period.

3.3.3 Recommendations

For the near term, the following actions are recommended:

- The requirement to overhaul these pumps in accordance with the TRS at Baseline Overhaul should be deleted from the DDG-37 Class SARP Planning Document. They should be overhauled only if POT&I or the ship's CSMP proves it necessary.

- A note should be added to the Maintenance Index Page (MIP E-5/59-A6) calling for the cyclical open-and-inspect requirement for the main circulating pump (MRC 66 K32G N) to be accomplished before the ship's Regular Overhaul.

For the long term, the main circulating pump should be repaired or overhauled during follow-on Regular Overhaul as shown to be necessary by POT&I results and the ship's CSMP.

3.4 AUXILIARY SALT WATER CIRCULATING PUMPS (APL 016050209 and 016120387)

The maintenance history of each of these pumps is discussed separately in Sections 3.4.1 and 3.4.2. However, since the pumps are so similar, the proposed maintenance strategy and recommendations are combined in Section 3.4.3.

These pumps are horizontally mounted, single-end suction, single-stage centrifugal pumps. The rotating elements are mounted on the shaft of the driving motor, and the pump casing is attached to the motor by means of a bracket. All of these pumps were installed during the ship's modernization.

Table 3-5 shows the material characteristics of each of these pumps. Each pump has an impeller made of gun metal and casing wearing rings made of valve bronze. The impeller wearing rings are manufactured from bearing bronze on pump APL 016050209 and from gun metal on pump APL 016120387. The pump casings are bearing bronze and gun metal, respectively. Each pump has shaft sleeves manufactured from Ni-Cu-Al Alloy (MIL QQ-N-286).

Table 3-5. MATERIAL CHARACTERISTICS OF AUXILIARY SALT WATER CIRCULATING PUMPS

Part	APL 016050209 (DDG-37 and -46)	APL 016120387 (DDG-38 through -45)
Impeller	Gun Metal	Gun Metal
Casing	Bearing Bronze	Gun Metal
Impeller Wearing Ring	Bearing Bronze	Gun Metal
Casing Wearing Ring	Valve Bronze	Valve Bronze
Shaft Sleeve	Ni-Cu-Al Alloy (MIL QQ-N-286)	Ni-Cu-Al Alloy (MIL QQ-N-286)

Each pump has the function of supplying cooling water to an associated turbogenerator auxiliary condenser, lube oil cooler, and air cooler.

3.4.1 Auxiliary Condenser Salt Water Circulating Pump (APL 016050209)

Background

These pumps are manufactured by Frederick Iron and Steel, Inc. Four of them are installed in each of the DDG-37 and the DDG-46. Both of these ships completed their modernization early in 1970; therefore, the maintenance history of these pumps extends through almost the entire MDS data period of 1 January 1970 through 30 September 1977.

Discussion

The average burden per component operating year reported for this pump is 22.4 man-hours, about the same as for the other auxiliary salt water circulating pump installed on DDG-37 Class ships. Approximately 0.5 JCN per component operating year was reported against this pump. No CASREPs were reported on this pump during the period 1 July 1973 through 30 September 1977.

Parts usage data for this pump, shown in Table 3-2, reveal that thirteen impeller and ten casing wearing rings have been replaced. This is a rate of 0.26 and 0.20 per equipment per operating year, respectively. Inspection of the data shows that wearing ring replacement often occurred in multiple quantities on a given pump. PMS requires an annual inspection of pump internal parts in MIP E-017/296-21. Since pump internals were inspected annually and wearing rings were replaced at such a low rate, it is concluded that wearing ring wear is not a problem in these pumps.

Five impellers have been ordered for this pump, indicating that five of the eight installed pumps required new impellers during the data period of approximately 6.3 operating years, or seven calendar years. All but one impeller lasted more than four years. Analysis of impeller replacement data for the other salt water circulating pump (APL 016120387, as discussed in Section 3.4.2) indicates a definite impeller wearout trend for that pump. Both pumps' impellers are made of the same material (gun metal). Although the sample size is too small to indicate a similar trend for this pump, it is likely that the same impeller wearout trend occurs for both pumps. Therefore, the maintenance strategy and recommendations for this pump are discussed with the recommendations for the other pump in Section 3.4.3.

3.4.2 Auxiliary Condenser Salt Water Circulating Pump (APL 016120387)

Background

These pumps were manufactured by the M.T. Davidson Company. Four of these pumps are installed in each of the hulls DDG-38 through DDG-45. No

maintenance data are available on DDG-41 because that ship did not complete its modernization before the end of the data period.

Discussion

The average Ship's Force and IMA burden per component operating year for this pump is 21.6 man-hours, about the same as for the auxiliary salt water circulating pumps installed on DDG-37 and DDG-46. Job Control Numbers have been initiated at a rate of approximately 0.63 per component operating years for this pump. Four CASREPs have been reported against this pump during the data period

Wearing Rings

Parts usage data show that impeller and casing wearing rings have been replaced at the rate of 0.55 and 0.61 per component operating year, respectively. This is a significantly higher rate of replacement than was shown for the other auxiliary circulating pump. Study of the data reveals that wearing rings were often replaced in multiple quantities and that actual maintenance actions involving wearing ring renewal occurred at a significantly lower rate, about 0.4 action per component operating year, or 2.6 years between replacements, on the average.

It is believed, however, that wearing rings can provide satisfactory operation for considerably longer than the 2.6 years between replacements that has been experienced without causing serious degradation in pump performance. The principal reason for this belief is that studies and tests conducted by NAVSECPHILADIV* have shown that the criterion of two times the design clearance used to determine the need for wearing ring replacement is more conservative than is required for pumps much more complex than the auxiliary circulating pumps. The NAVSECPHILADIV tests were terminated before the entire range of clearances could be evaluated. Further, MDS narratives indicate that wearing rings were replaced in almost all cases due to excessive wearing ring clearances or due to impeller replacement and not due to pump failure.

Shaft Sleeves

Shaft sleeves have been replaced on these pumps at the rate of 0.39 per COY. This replacement rate is considerably higher than the 0.14 per COY replacement rate experienced by the other pump (APL 016050209). No reason for this difference was found, but several observations lead to the conclusion that they can operate satisfactorily for the same period as the shaft sleeves on the other pump.

The first point is that the shaft sleeves on both pumps are made of the same material, Ni-Cu-Al alloy (MIL QQ-N-286). Second, the seven ships

*NAVSECPHILADIV Letter Report to NAVSEA (PMS-306) Ser. 153, 16 March 1976.

with this pump include one group of three ships that have accumulated 49.5 COY and have experienced a replacement rate of 0.18 shaft sleeves per COY, and another group of four ships with 64.8 COY of operating experience that have replaced shaft sleeves at a rate of 0.57 per COY. It is believed that the significantly higher wearing ring replacement rate of the second group of ships was a result of preventive pump maintenance actions involving wearing ring replacement. Finally, the shaft sleeves on the two auxiliary salt water circulating pumps of the same general design on the FF-1052 Class each experienced a shaft sleeve replacement rate of about 0.15 per COY.* The shaft sleeves on one of these pumps, with over half of the total component operating time, has shaft sleeves of the same material. The other pump's shaft sleeves were manufactured from a harder material.

Impellers

Eighteen impellers have been replaced on these pumps. Erosion of the impeller is the reason most frequently cited in MDS narratives for impeller replacement. The action initiation dates (as reported in MDS) of those maintenance actions indicating an impeller replacement have been used to calculate the theoretical probability distribution of the times to impeller replacement. (The details of the development of this distribution are shown in Appendix C.) The mean time to impeller replacement is approximately four years, and these impellers have demonstrated a distinct wearout pattern: about 75 percent of all impellers are replaced between the third and sixth year of operation, and 98 percent of all impellers are replaced by the end of six years of operation (see Table 3-6).

Table 3-6. AUXILIARY SALT WATER PUMP (APL 016120387) IMPELLER REPLACEMENT DATA BASED ON THEORETICAL FAILURE DISTRIBUTION (DATA FROM APPENDIX C)

Impeller Age at Replacement (Years)	Cumulative Percent Replaced
1	1
2	5
3	22
4	54
5	84
6	98
7	99

*ARINC Research Corporation, *Destroyer Engineered Operating Cycle, System Maintenance Analysis, FF-1052 Class Salt Water Circulating System, SMA 110-256*, Publication 1646-03-25-1654, September 1976.

These salt water circulating pumps have gun metal impellers. Gun metal impellers are known to erode and wear out after several years of service. Therefore, the conclusions reached through development of the probability distributions serve to confirm and quantify what is known through engineering analysis and observation. Section 3.4.3 presents the rationale for a maintenance strategy for these pumps on the basis of the above facts.

3.4.3 Maintenance Strategy

The discussion in this section applies to both models of auxiliary circulating water pumps (i.e., APL 016050209 and APL 016120387) installed on DDG-37 Class ships because they are functionally identical and both have gun metal impellers. This analysis is based specifically on the maintenance history of pump APL 016120387 because that is the only pump with enough data from which to draw statistical conclusions.

Each auxiliary salt water circulating pump must function satisfactorily to permit the operation of its associated turbogenerator.

The pump is basically reliable and can probably operate satisfactorily without major corrective maintenance until the impeller is severely eroded. The time to replacement of the impeller, discussed in Section 3.4.2, is at most five years. The Frederick Iron and Steel, Inc., pump (APL 106050209) has demonstrated a low rate of replacing wearing rings and shaft sleeves, as shown in Section 3.4.1. The M.T. Davidson Company pump (APL 106120387) shows the potential of operating satisfactorily without wearing ring or shaft sleeve replacement for at least as long as the impeller, as shown in Section 3.4.2.

Failure to operate satisfactorily is defined as the inability of the pump to perform its function of providing adequate cooling water to the turbogenerator heat exchangers. The symptoms of this inability to operate satisfactorily are a reduction in pump discharge pressure, low condenser vacuum, and increased temperature rise across the heat exchangers.

The consequences of the failure of this pump to perform are not catastrophic. Each pump is required for the operation of its associated turbogenerator, but normally only two of four turbogenerators are required for the ship's operations. In addition, Ship's Force is capable of overhauling these pumps and all spare parts required for an overhaul are included in the ship's allowance.

These considerations suggest the following feasible alternative maintenance strategies:

- Run to failure
- Overhaul at a fixed interval
- Replace impeller material with material less subject to erosion, and run to failure
- Inspect annually, replace parts as necessary (present policy)

A special investigation is required to determine the suitability of changing the impeller material. This analysis indicates that the pumps can operate satisfactorily with their present materials and under the maintenance strategy defined below; therefore, there is no need to change materials. However, a careful engineering and cost analysis may show that there would be economic benefits from making such a change.

Comparing the run-to-failure and overhaul-at-fixed-interval policies, one is led to prefer the overhaul-at-fixed-interval policy because of the observed increasing replacement rate of the pump impeller. If the fixed interval chosen is too long, the pump will be operated under a run-to-failure policy by default; that is, most pumps will fail before the fixed overhaul time is reached. These failures can result from either the failure of the impeller or of other wearing parts. If the fixed time to overhaul is set too short, few pumps will fail and the maintenance policy will be similar to the present policy. In that case, various wearing parts will be replaced as the need for replacement is determined through inspection.

Table 3-6 indicates that if the overhaul interval is set at three years, 22 percent of all pumps would fail and have their impellers replaced before overhaul. If the interval is set at four years, 54 percent would fail; and if it is set at five years, 84 percent would fail and have their impellers replaced before overhaul. However, the data in Table 3-6 most likely reflect replacements that were made before impeller erosion was severe enough to cause operational failure of the pump. This deduction results from the fact that annual inspections of the pump are required by PMS and that, as in the case of wearing rings, visible or measurable deterioration is likely to take place a considerable time before functional failure. It is also supported by the evidence that no catastrophic failures attributable to the pump end of the auxiliary circulating pump and motor were found in the MDS data.

These considerations indicate that the replacement distribution shown in Table 3-6 is conservative. The most straightforward way to make it more realistic is to assume that the failure distribution has the same increasing rate as the observed impeller replacement probability distribution, but that failures occur a fixed period later than the observed replacement.* In other words, the assumption is made that each replaced impeller would have operated satisfactorily for a fixed period beyond the point that replacement took place and then caused an operational failure of the pump. An analysis in Appendix D supports setting a five-year interval between pump overhauls on the basis of that assumption. During a five-year interval, from 20 percent to 50 percent of all pumps would be expected to fail before overhaul. If the assumed interval between replacement and failure is one-year, the 20 percent figure is applicable; if the assumed interval is two years, the 50 percent figure is applicable. The five-year

*At least 7 of the 18 impellers replaced were issued to the maintenance man at least six months after the initiation of the maintenance action.

interval was selected because it is the longest interval between pump openings that has a good probability of preventing a significant number of pump failures and because the consequences of being wrong and consequently experiencing a high number of failures are not serious*. If the pump has not failed after five years, the impeller and other wearing parts will in all likelihood evidence significant wear, and overhaul can renew the pumps and prevent failures.

Some pumps will be opened and inspected within less than five years because of failures of the pump's close-coupled motors.** These inspections will further reduce pump failures by allowing for the early replacement of wearing parts, on the basis of visual inspection. Random pump and motor failures will tend to randomize the age of the pumps, so that not all pumps will be approaching a five-year overhaul at once.

Overhaul of the auxiliary circulating pumps at Baseline Overhaul is recommended so that these pumps will be in the material condition required to operate throughout the extended operating cycle with the least possible chance of failure. Pump overhaul in accordance with the applicable TRS is called for in the DDG-37 Class SARP Planning Document. This study supports that recommendation. However, overhaul of close-coupled pumps is considered within Ship's Force and IMA capability and they have successfully overhauled pumps of this type in the past. Furthermore, as pump age becomes randomized, the Ship's Force, with IMA assistance, will necessarily have to overhaul these pumps. The overhaul of these pumps at Baseline Overhaul will require that sufficient parts, particularly wearing rings and impellers, are available in order to complete the overhauls expeditiously.

A previously documented SMA† addresses the general problems of centrifugal pump repair. It recommends that a centrifugal pump repair manual be developed and issued that would address wearing ring installation, ball bearing fit-up criteria, ball bearing handling and installation, pump and piping alignment, and proper repair techniques. That recommendation applies equally to the maintenance of these pumps.

3.4.4 Recommendations

These recommendations apply to both the auxiliary circulating water pumps installed on DDG-37 Class ships.

For the near term, the following actions are recommended:

- The auxiliary circulating pumps should receive a Class "B" Overhaul at BOH in accordance with the applicable TRS.

*Experiencing a high number of failures is, by default, a run-to-failure policy, as is discussed above.

**Disassembly of the pump is required in order to repair the motor.

†ARINC Research Corporation, *Destroyer Engineered Operating Cycle, System Maintenance Analysis, DDG-37 Class Firemain and Auxiliary Machinery Cooling Water Systems, SMA 37-201-521*, Publication 1652-03-10-1715, February 1978.

- The PMS requirement to annually open and inspect these pumps (MRC 21 A14V A) should be deleted.
- The pumps should be overhauled at five-year intervals.

For the long term, the Ship's Force should be provided with a suitable centrifugal pump repair manual.

3.5 AUXILIARY CIRCULATING PUMP MOTORS AND MOTOR STARTERS

3.5.1 Background

Each auxiliary circulating pump is close-coupled to and driven by a 25-hp motor. The motors installed in DDG-38 through DDG-45 were manufactured by the General Electric Company (APL 175503584). There is no post-modernization maintenance data available on DDG-41. The motors installed on DDG-37 were manufactured by the Reliance Electric Company (APL 174752378) and in DDG-46 by the Continental Electric Company, Inc. (APL 174180291).

The motor starters installed in DDG-38 through DDG-40 and DDG-42 through DDG-45 were manufactured by the General Electric Company (APL 151406071). The motor starters installed in DDG-37 and DDG-46 were manufactured by the Ward Leonard Electric Co. (APL 151801999). The motor starters installed in DDG-41 could not be identified.

3.5.2 Discussion

Motors

There have been ten CASREPs on nine different motors on these ships. Five CASREPs have been for bearing problems and five for burned out windings. Apparently failures of these motors result in CASREPs because failure of the circulating pump puts the associated turbogenerator out of commission. However, the rate of CASREP submission is only 0.03 bearing CASREP and 0.03 winding CASREP per COY.

MDS data are inconclusive in identifying maintenance problems of these motors because most of the JCNs consist of parts requisitions without man-hour data or narratives. However, all of the maintenance man-hours reported against the four Continental Electric Company motors (APL 174180291) can be attributed to two pumps that were submerged during the same incident. There was no CASREP for this incident.

The burden of 3.4, 0.8, and 7.1 man-hours per COY on the General Electric, Reliance, and Continental motors, respectively, is very low. Ship's Force reports that these motors are reliable. Parts usage data are shown in Table 3-2.

It is concluded that a run-to-failure policy for these motors is

appropriate because of their low maintenance burden, the random nature of failures, and the capability of Ship's Force, assisted by an IMA, to repair the motors. Because of the random nature of motor failures, no benefit will result from the routine overhaul of these motors at BOH.

Ball bearing installation procedures for motors and pumps were discussed in some detail in a previously documented SMA.* The recommendations made there are appropriate to all motors. They call for providing ships with ball bearing heaters and including a section on ball bearing removal and replacement in the proposed centrifugal pump maintenance manual (see Section 3.4.3 of this SMA). These measures will serve to standardize and improve motor maintenance and enhance equipment availability.

Controllers

Very little maintenance has been reported against the motor controllers in this system. Review of the applicable PMS procedures indicates that they are adequate to maintain these equipments in good material condition. There are no data to support the requirement that these equipments be overhauled during Baseline Overhaul.

3.5.3 Recommendations

The following near-term actions are recommended:

- The requirement to routinely overhaul the auxiliary circulating pump motors in accordance with the TRS at Baseline Overhaul should be deleted. They should be overhauled only if a POT&I or the ship's CSMP indicates it is necessary.
- The requirement to routinely overhaul the auxiliary circulating pump motor controllers at Baseline Overhaul should be deleted. They should be overhauled only if a POT&I or the ship's CSMP indicates it is necessary.
- Ship's Force should be provided with suitable ball bearing heaters.
- It should be ensured that the recommended centrifugal pump overhaul manual (see Section 3.4.3) contains a section on ball bearing removal and replacements.

3.6 SALT WATER STRAINER (APL 755170019)

3.6.1 Background

The salt water strainer is a duplex strainer placed to protect the associated turbogenerator lube oil cooler (APL 030300091).

**Ibid.*

Four of these strainers are installed on each of the hulls DDG-38, 39, 40, 42, 43, and 45. Three are installed on DDG-44. The APL of the other strainers in this service could not be determined.

3.6.2 Discussion

The basket perforations in these strainers are larger than the inner diameter of the lube oil cooler tubes: the basket perforations are 0.25 inch and the tube inner diameter is 0.180 inch. Good design practice requires that the strainer basket perforations be smaller than the tube inner diameter in order to intercept debris that can clog the cooler tubes.

This situation was discovered during a ship visit. Ship's Force reported that the lube oil cooler required cleaning as frequently as monthly because of clogging with debris that had passed through the strainer. This strainer should be replaced with one that will afford protection to the lube oil cooler and prevent clogging of the cooler.

Correction of this discrepancy is good design practice and will contribute to the overall reliability of the turbogenerators on these ships.

3.6.3 Recommendation

For the near term, a ShipAlt to install an appropriate strainer should be developed and accomplished.

3.7 EXPANSION JOINTS

3.7.1 Background

There are five expansion joints in each main circulating system of DDG-37 Class ships. Three of these are 28 inches in diameter or larger and are located in the scoop injection inlet line, the main circulating pump discharge line, and the main circulating water overboard discharge line. One 8-inch expansion joint is located in the main lube oil cooler inlet line and another 8-inch expansion joint is located in the main lube oil cooler overboard discharge.

3.7.2 Discussion

Very little maintenance of the expansion joints was evident in the maintenance data and no CASREPs have been reported against them.

The NAVSHIPS Technical Manual (NSTM), Chapter 9480, states that the maximum service life of expansion joints located in manned spaces is ten years and that external and internal inspections are required each five years. Expansion joints can be changed with the ship in the water, provided the sea-valves are tight or a cofferdam is placed over the applicable sea-chests. For maximum safety, both precautions should be taken.

The routine replacement of the expansion joints in the scoop injection inlet line, the main circulating pump discharge line, and the main circulating water overboard line is not supported by maintenance experience because these components have experienced a low maintenance burden. However, it is recommended that the expansion joints be routinely renewed at BOH if they are more than five years old and will, therefore, be overage by the end of the extended operating cycle. They should also be renewed, regardless of age, if inspection reveals significant deterioration.

3.7.3 Recommendations

For the near term, the requirement to routinely replace the expansion joints in the scoop injection inlet line, the main circulating pump discharge line, and the main circulating water overboard line should be deleted from the DDG-37 Class SARP Planning Document and be replaced by a requirement to replace each expansion joint in the Salt Water Circulating System on an individual basis only if it is more than five years old or if inspection shows replacement to be necessary.

3.8 RECOMMENDED MAINTENANCE STRATEGY FOR SALT WATER CIRCULATING SYSTEM COMPONENTS

This analysis has shown that a run-to-failure maintenance strategy is feasible for most components of this system.

The main circulating pump turbine and pump have been shown to be very reliable and not subject to catastrophic failure. However, it is anticipated that some maintenance on the turbine governor will be required during the intra-cycle period and that this maintenance is normally within the capabilities of Forces Afloat. Should major maintenance be required on the turbine reduction gears, industrial assistance should be used.

The auxiliary circulating pumps have also been shown to be reliable, although they are subject to severe impeller erosion and wearout after three to five years of operation. The ability of the Ship's Force to affect repairs and limit the consequences of pump failure makes a run-to-failure policy feasible. However, a significant number of failures can be avoided by overhauling these pumps at five-year intervals.

Auxiliary circulating pump motors and controllers have also been shown to be reliable. Motor and controller failures are random and therefore are not recommended as candidates for periodic overhaul. Motor bearing replacement is within the capability of Ship's Force, and motor rewinding is normally accomplished by an IMA. Controller maintenance is within the capability of Ship's Force.

Expansion joints must be replaced at ten-year intervals, in accordance with NSTM 9480.

3.9 BASELINE OVERHAUL REQUIREMENTS

The Baseline Overhaul concept of the DDEOC Program is to provide the maintenance necessary to restore a system to a condition in which, with a well engineered and executed maintenance program, it can be expected to perform satisfactorily over an extended operating cycle. In keeping with the policy, specific Baseline Overhaul requirements for the main and auxiliary circulating water system are as follows:

- Main Circulating Pump Turbine - A depot-level Class "B" Overhaul should be performed in accordance with TRS 0256-086-602. This recommendation is based on the fact that only a depot-level industrial facility can adequately undertake the removal, repair, balancing, and reinstallation of a steam turbine with consistent success.
- Auxiliary Circulating Pumps - A depot-level Class "B" Overhaul should be performed in accordance with the applicable TRS. This action will help ensure that these pumps will operate satisfactorily throughout an extended operating cycle.
- Expansion Joints - Expansion joints should be replaced only if they are more than five years old or if inspection shows replacement to be necessary.

This analysis does not support the routine Class "B" Overhaul of the main circulating pump or of motors and controllers, as recommended in the "DDG-37 Class SARP Planning Document", dated February 1978. All other actions recommended in that document for SWBS 256 and 520 should be accomplished because they will contribute materially to the ability of the ship to operate throughout an extended operating cycle.

Table 3-7 lists those BOH repairs for SWBS 256 and 520 that are recommended for change or deletion and the rationale for the change.

3-10 INTRA-CYCLE AND FOLLOW-ON BOH REQUIREMENTS

Ship's Force is able to maintain most system components, but it cannot provide major maintenance for the main circulating pump turbine reduction gears or sea valves, nor can it rewind and balance auxiliary circulating pump motors. Ship's Force can repair the main and auxiliary circulating pumps, replace bearings on the auxiliary circulating pump motors, and maintain the motor starters. With IMA assistance, Ship's Force can maintain the main circulating pump turbine governor.

The maintenance actions that cannot be performed by the Ship's Force do not lend themselves to preventive maintenance and are normally accomplished only as corrective maintenance. Therefore, the only intra-cycle maintenance requirements should be the existing PMS actions as modified by recommendations of this report and the Ship's Force performance of all

Table 3-7. RECOMMENDED CHANGES TO THE DDG-37 CLASS SARP PLANNING DOCUMENT

SWLIN	Description	Change	Reason for Change
256A01A	Expansion Joints - Replace the three expansion joints in the main circulating system: • Scoop injection inlet line • Main circulating pump discharge line • Main circulating water overboard discharge line	Replace each of the following expansion joints only if it is more than five years old or if inspection shows replacement to be necessary: • Scoop injection inlet line • Main circulating pump discharge line • Main circulating water overboard discharge line • Main lube oil cooler inlet line • Main lube oil cooler overboard discharge line	The DDG-37 Class SARP Planning Document refers to only the expansion joints noted. Chapter 9480 of the NSTM calls for replacing expansion joints in manned spaces each ten years or when inspection shows replacement to be necessary. It is expedient to take steps to ensure that these expansion joints do not have to be replaced during the extended operating cycle.
256A02	Auxiliary Circulating Pump Motor - Overhaul in accordance with TRS 0256-086-____.	Overhaul based on POT&I or CSMP.	A run-to-failure philosophy is recommended for motors based on the fact that bearing replacements and motor rewindings are random events and are hard to predict.
256A02	Motor Controller - Class "B" Overhaul.	Overhaul based on POT&I or CSMP.	Motor controllers have experienced little intra-cycle maintenance burden and current PMS procedures are adequate to maintain them. There are no data to support the routine overhaul of motor controllers.
256A03A	Main Circulating Pump - Overhaul in accordance with TRS 0256-086-____.	Overhaul based on POT&I or CSMP.	A run-to-failure maintenance strategy for the pump, together with its low maintenance burden, precludes the need to overhaul the main circulating pump at BOH. There was no conclusive evidence that overhauling these pumps without regard to material condition would be cost-effective.

corrective maintenance on system components, supported by an IMA as necessary. These actions include overhauling the auxiliary circulating pumps at five-year intervals.

Main circulating pump turbine reduction gear maintenance, while considered unlikely during the intra-cycle, should be accomplished by an industrial activity if required.

At follow-on ROH, the main circulating pump turbine should be singled out for special scrutiny to identify conditions that require those components to be overhauled in order to operate reliably throughout the subsequent operating cycle. Also, expansion joints in manned space must be replaced at ten-year intervals, in accordance with NSTM Chapter 9480. Sea valves should also be overhauled as necessary at follow-on ROHs.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

This review of experience has led to the following conclusions:

- System components are generally reliable and their maintenance burdens are not excessive
- Most repairs to the main and auxiliary salt water circulating systems can be accomplished by Ship's Force with IMA assistance
- Repairs to the main circulating pump turbine reduction gears should be accomplished only by an industrial activity
- The use of a proposed centrifugal pump repair manual and the provision of bearing heaters to ships can improve the quality of maintenance performed on the auxiliary circulating pumps and motors
- A run-to-failure maintenance strategy is appropriate for all system components except the auxiliary circulating pumps
- Auxiliary salt water circulating pumps are subject to wearout and should be overhauled at five-year intervals
- Expansion joints should be replaced at BOH if they are more than five years old or if inspection shows replacement to be necessary
- Changes to main circulating pump turbine PMS can save many maintenance man-hours with little effect on system reliability
- The duplex strainer protecting the turbogenerator lube oil cooler is improperly sized
- With only minor changes, the PMS requirements for the salt water circulating system will be adequate

4.2 RECOMMENDATIONS

Corrective actions and improvements required for the Salt Water Circulating System are grouped as follows:

- Baseline Overhaul Requirements
- Intra-Cycle Maintenance Requirements

- Follow-On ROH Requirements
- Reliability and Maintainability Improvements
- Planned Maintenance System Changes
- Industrial Facility Improvements
- IMA Improvements
- Integrated Logistic Support (ILS) Improvements

Table 4-1 summarizes all recommendations resulting from this Review of Experience. A detailed list of recommended PMS changes is included in the DDEOC MRC Evaluation Table of Appendix E. Action items resulting from these recommendations are listed in the DDEOC Action Table of Appendix F.

Table 4-1. SUMMARY OF ROE RECOMMENDATIONS FOR THE DDG-37 CLASS SALT WATER CIRCULATING SYSTEM

Component	Recommendation
Baseline Overhaul Requirements	
Main Circulating Pump Turbine	Overhaul in accordance with TRS 256-086-601.
Main S.W. Circulating Pump	Overhaul as shown to be necessary by POT&I or ship's CSMP.
Auxiliary Circulating Pump	Overhaul in accordance with TRS 256-086-600 or TRS 256-086-619.
Auxiliary Circulating Pump Motor	Overhaul as shown to be necessary by POT&I or ship's CSMP.
Auxiliary Circulating Pump Motor Controllers	Overhaul as shown to be necessary by POT&I or ship's CSMP.
Expansion Joints	Replace if more than five years old or if inspection shows replacement to be necessary.
Intra-Cycle Maintenance Requirements	
All Equipments of the Salt Water Circulating System	Accomplish PMS requirements as modified by the recommendations of this report.
Auxiliary Circulating Pump	Overhaul at five-year intervals.
Follow-On ROH Requirements	
Main Circulating Pump Turbine	Overhaul as shown to be necessary by POT&I or ship's CSMP.
Main Circulating Pump	Repair or overhaul as shown to be necessary by POT&I or ship's CSMP.
Reliability and Maintainability Improvements	
Auxiliary Circulating Pump	Overhaul at five-year intervals.
Duplex Strainer	Develop a ShipAlt to re[illegible]ce the existing duplex strainer with an appropriately sized unit.
Planned Maintenance System Changes	
Main Circulating Pump	Change the periodicity of the requirement to back-flush the lube oil cooler from monthly to quarterly on MIP E-5/59-A6, MRC 94 E87F N.
	Add a note to perform the cyclical open-and-inspect requirement of the pump prior to the ship's regular overhaul on MIP E-5/59-A6, MRC 66-K32G N.
	Change the periodicity of the requirement to inspect the carbon packing and gear casing from cyclical to 36 months on MIP E-5/59-A6, MRC 65 H16V N.
	Change the periodicity of the requirement to inspect the reduction gears from cyclical to 36 months. Add a note that reduction gear maintenance should be performed by an industrial activity on MIP E-5/59-A6, MRC 65 H16W N.
Auxiliary Circulating Pump	Delete the annual open-and-inspect requirement for MIP E-17/296-21, MRC 21 A14V A.
Industrial Facility Improvements -- None	
IMA Improvements -- None	
Intergrated Logistic Support (ILS) Requirements	
Centrifugal Pumps and Motors	Provide Ship's Force with a suitable Centrifugal Pump Repair Manual.*
	Provide suitable ball-bearing heater ovens.*

*These recommendations were originally made in the DDG-37 Class Firemain and Auxiliary Machinery Cooling Water Systems SMA (SMA 37-201-521). Detailed rationale for these recommendations are contained in the referenced report, ARINC Research Publication 1652-03-15-1752.

LIST OF REFERENCES

The specific sources of information used as a basis for the System Maintenance Analysis of the Salt Water Circulating System are listed below:

1. Generation IV MDS Part and Maintenance Data for DDG-37 Class for the period 1 January 1970 through 30 September 1977.

2. CASREP Narrative Summaries for the period 1 July 1973 to 30 September 1977.

3. Technical Manual - *Turbine Driven Main Condenser, Circulating Pump,* Warren Pumps, Inc., NAVSHIPS 347-3146, January 1959.

4. Technical Manual - *Horizontal Close-Coupled Pumps Sea (Salt) Water,* Frederick Iron and Steel, Inc., NAVSHIPS 0947-127-4010, August 1968.

5. Technical Manual - *SSTG Condenser Circulating Pumps,* M.T. Davidson Company, NAVSHIPS 0947-128-3010, November 1969.

6. Ship Information Book, DLG-9 (DDG-40):

   Volume 1, Hull and Mechanical, NAVSHIPS 0905-475-4010.

   Volume 2, Part 1 of 2, Piping, NAVSHIPS 0905-475-4020.

   Volume 2, Part 2 of 2, Piping, NAVSHIPS 0905-475-4030.

7. Engineering Operational Sequencing System, DDG-40.

8. Type Commanders COSAL, SURFLANT and SURFPAC, dated 28 April 1976 and 23 June 1976, respectively.

9. Allowance Parts Lists (APLs) for selected components of the salt water circulating system.

10. Trip Report (13-14 March 1978); ARINC Research Corporation visit to: USS MAHAN (DDG-42), USS PRATT (DDG-44).

11. NAVSEC PHILADIV Letter Report to NAVSEA (PMS-306), Ser. 153, 16 March 1976.

12. OPNAVINST 4790.4, Material Maintenance Management (3M) Manual, Volumes I and II, June 1973.

13. PERA (CRUDES), DDG-37 Class Repair Profile, June 1977.

14. *DDG-37 SARP Planning Document,* ARINC Research Publication 1809-01-2-1711, February 1978.

15. *Destroyer Engineered Operating Cycle, System Maintenance Analysis, FF-1052 Class Salt Water Circulating System, SMA 110-256,* ARINC Research Publication 1646-03-25-1654, September 1977.

16. *Destroyer Engineered Operating Cycle, System Maintenance Analysis, DDG-37 Class Firemain and Cooling Water System, SMA 37-201-521,* ARINC Research Publication 1652-03-10-1715, February 1978.

17. Naval Ships' Technical Manual, Chapter 9480, Piping Systems, NAVSHIPS 0901-480-0002, 1 July 1973.

APPENDIX A

BOUNDARIES OF SALT WATER CIRCULATING SYSTEM FOR DDG-37 CLASS SHIPS

The Salt Water Circulating System discussed in this report consists principally of the components listed in Table A-1. The table also lists APL numbers and APL quantities per ship. In developing this table, an attempt was made to resolve inconsistencies among Type Commander's COSAL and MDS reporting data, but all such inconsistencies could not be resolved. This configuration is the best estimate from all available data sources. A dash (-) indicates that no configuration could be determined.

Table A-1. COMPONENTS OF SALT WATER CIRCULATING SYSTEM FOR DDG-37 CLASS

Nomenclature	EIC	APL/CID	Quantity by Hull Number									
			DDG-37	DDG-38	DDG-39	DDG-40	DDG-41	DDG-42	DDG-43	DDG-44	DDG-45	DDG-46
MN. CIRC. WATER SYSTEM												
Pump, Ctfgl, 22,000 gbm, 13 psi	FB03	016020490	2	2	2	2	2	2	2	2	2	2
Turbine, Stm, Mn. Circ. Pmp.		057950046	2	2	2	2	2	2	2	2	2	2
Pump, Rty, Pwr, 3.50 gpm, 500 psi		016010283	2	2	2	2	2	2	2	2	2	2
Filter FD Press		480110338	2	2	2	2	2	2	2	2	2	–
Cooler Fd, 1.70 Sq.Ft. Clg. Sur.		030130287	2	2	2				2			
Cooler Fd, 2.71 Sq.Ft. Clg. Sur.		030130394				2	2	2		2	2	2
Valve, Relf, 6.00 IPS, 2 psi Set		882117275	2	2	2	2	2	2	2	2	2	2
Valve, Gate, 36.00 IPS, 30 psi	FB04	882041495	2	2	2	2	2	2	–	2		
Valve, Gate, 36.00 IPS, 30 psi		882042125							–		2	2
Valve, Gate, 32.00 IPS, 30 psi		882041494	2	2	2	2	2	2	–	2		
Valve, Gate, 32.00 IPS, 30 psi		882042124							–		2	2
Valve, Gate, 27.00 IPS, 30 psi		882041492	2	2	2	2	2	2	–	2		
Valve, Gate, 27.00 IPS, 30 psi		882042147							–		2	2
AUX. CIRC. WATER SYSTEM												
Pump, Ctfgl, 1800 gpm, 15 psi MCC	310E	016050209	4									4
Pump, Ctfgl, 1800 gpm, 15 psi MCC		016120387		4	4	4	4	4	4	4	4	
Motor, ac, 440v, 25 hp		174180291										4
Motor, ac, 440v, 25 hp		174752378	4									
Motor, ac, 440v, 25 hp		175503584		4	4	4	4	4	4	4	4	
Starter Motor, SZ2		151406071		4	4	4	–	4	4	4	4	
Starter Motor, SZ2		151801999	4									4
Strainer Dplx, 2.500 In.		755170019	–	4	4	4	–	4	4	3*	4	–

*Other strainer unknown.

APPENDIX B

CASREP SUMMARY

CASREPs for the DDG-37 Class Salt Water Circulating System covering the period 1 July 1973 to 30 September 1977 are shown in Table B-1. The table is based on 26 CASREPs submitted by ten ships that operated for a total of 31.5 ship operating years during this period. Therefore, the rate of CASREP submission against the Salt Water Circulating System for this period is:

$$\frac{26 \text{ CASREPs}}{31.5 \text{ Ship Operating Years}} = 0.83 \text{ CASREP per Ship Operating Year}$$

Table B-1. CASREP ANALYSIS SUMMARY FOR THE DDG-37 CLASS SALT WATER CIRCULATING SYSTEM

Reason for CASREP	Number of CASREPs	Percent of Total CASREPs	Number of Ships Reporting
Auxiliary Circulating Water Pump			
Wear	4*		
Subtotal	4	15.4	3
Auxiliary Circulating Water Pump Motor			
Bearing Failure	5		
Winding Failure	5		
Subtotal	10	38.5	7
Main Circulating Pump Turbine			
Gear Wear	2		
Slinger Ring	1		
Turbine Failure	1		
Improper Repair	1		
Subtotal	5	19.2	4
Throttle Valve			
Improper Repair	1		
Subtotal	1	3.8	1
Exhaust Relief Valve			
Normal Wear	1		
Subtotal	1	3.8	1
Major Valves			
Corrosion	1		
Jammed Shut	1		
Leak	2		
Subtotal	4	15.4	2
Piping			
Normal Deterioration	1		
Subtotal	1	3.8	1
Total	26	99.9	--

*One of these CASREPs was combined with a CASREP for motor bearing failure.

APPENDIX C

ESTIMATION OF TIME-TO-REPLACEMENT DISTRIBUTION FOR AUXILIARY CIRCULATING PUMP IMPELLERS (USING WEIBULL HAZARD PLOTS)

The data used to estimate the time-to-replacement distribution of Auxiliary Circulating Pump (APL 016120387) impellers consist of the reported time to impeller replacement, as reported in MDS data. The data used to indicate replacement are those that were recorded in MDS as indicating the beginning of the action. Table C-1 records these times in quarters from the end of conversion until the first impeller replacement. All of these pumps were installed during the conversion and all replacements are first replacements. Asterisks indicate pumps that operated to the end of the data period without replacement. Those entries show the time from the end of conversion to the end of the data period. Derivation of the other columns is explained below.

The Weibull distribution is a general probability distribution that describes the time-to-failure of a device over a wide range of cases where the failure probability varies with time. Nelson* describes a graphic method of obtaining the parameters of that distribution using censored failure data. The data in Table C-1 were used to identify the failure distribution of the auxiliary circulating pump impeller. Nelson's paper should be consulted for a more complete discussion and for a theoretical development of the procedures.

The first step is to order the data from the smallest to the largest failure time, including censored observations, i.e., data in which no failures have occurred. The next steps are purely mechanical and are illustrated in Table C-1. They are: (1) number the observations in descending order, (2) invert the order number of the uncensored observations and multiply by 100, and (3) list the cumulative value of these products, starting from the top.

The next step is to plot the cumulative hazard against failure time data on Weibull hazard plotting paper. If the data points form a reasonably

*W. Nelson, "Hazard Plotting for Incomplete Failure Data", *Journal of Quality Technology*, No. 1, pp. 27-52, 1969.

Table C-1. DATA ON AUXILIARY CIRCULATING PUMP IMPELLER REPLACEMENTS BASED ON MDC ACTION INITIATIONS			
Quarters to Replacement	Order	1/Order × 100	Cumulative Hazard
5	28	3.57	3.57
10*	27	--	--
10*	26	--	--
10*	25	--	--
10*	24	--	--
10	23	4.35	7.92
10	22	4.54	12.45
11	21	4.76	17.22
12	20	5.00	22.22
12	19	5.26	27.48
12	18	5.56	33.04
13*	17	--	--
13	16	6.25	39.29
13	15	6.67	45.96
11	14	7.14	53.10
14	13	7.69	60.79
14	12	8.33	69.12
14	11	9.09	78.21
17	10	10.00	88.21
17	9	11.11	9[illegible].32
18	8	12.50	111.82
18	7	14.28	126.10
18	6	16.67	142.77
22*	5	--	--
22*	4	--	--
22*	3	--	--
22*	2	--	--
25*	1	--	--

*Censored observations.

straight line, then the Weibull distribution can be used to describe the data. If the data points do not form a straight line, then some other failure distribution must be found to describe the data.

The data are plotted in Figure C-1. The data points are judged to lie close enough to a straight line for the Weibull distribution to be applicable, although there is one outlying point indicating an early impeller replacement.

The Weibull distribution has two parameters. The location parameter is α and is read from the plot as the quarter in which the fitted line intersects with the 100 percent cumulative hazard point. The shape parameter is β and it can be determined by drawing a line parallel to the fitted line through the point in the upper left hand side of the drawing paper and determining where it intersects the shape parameter line. The formula for calculating the mean of the distribution is

$$\mu = \alpha\ \Gamma\ (1/\beta+1)$$

where Γ ( ) represents the gamma function (tabulated in any book of mathematical tables). The values of the parameters are α = 17 quarters and β = 3.9. The mean of the distribution is

$$\mu = 17\ \Gamma\ (1/3.9 + 1) = 17\ \Gamma\ (1.256) = 17\ (.905) = 15.4 \text{ quarters}$$

The cumulative probability of the time to impeller replacement, taken from the derived Weibull distribution, is plotted in Figure C-2.

The shape parameter indicates whether the Weibull distribution has an increasing or decreasing failure rate. A shape parameter of one indicates a constant failure rate and a shape parameter greater than one indicates an increasing failure rate. The value of the shape parameter for this distribution is 3.9, indicating a very rapidly increasing failure rate. This is illustrated by the replacement of about 75 percent of all impellers between the third and sixth year of operation and 98 percent by the end of six years of operation.

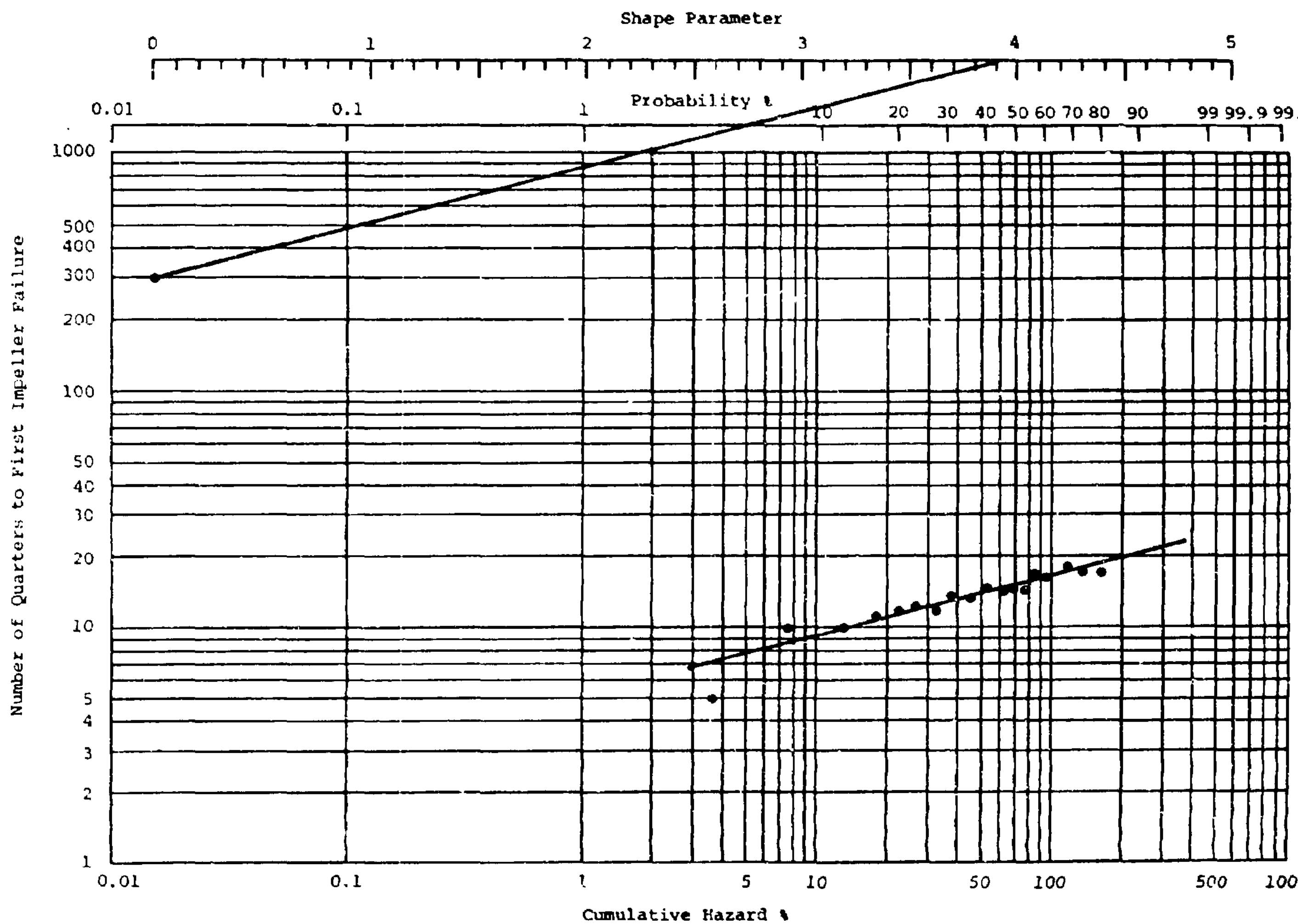

Figure C-1. WEIBULL HAZARD PLOT OF IMPELLER REPLACEMENTS FOR AUXILIARY CIRCULATING PUMP (APL 016120387)

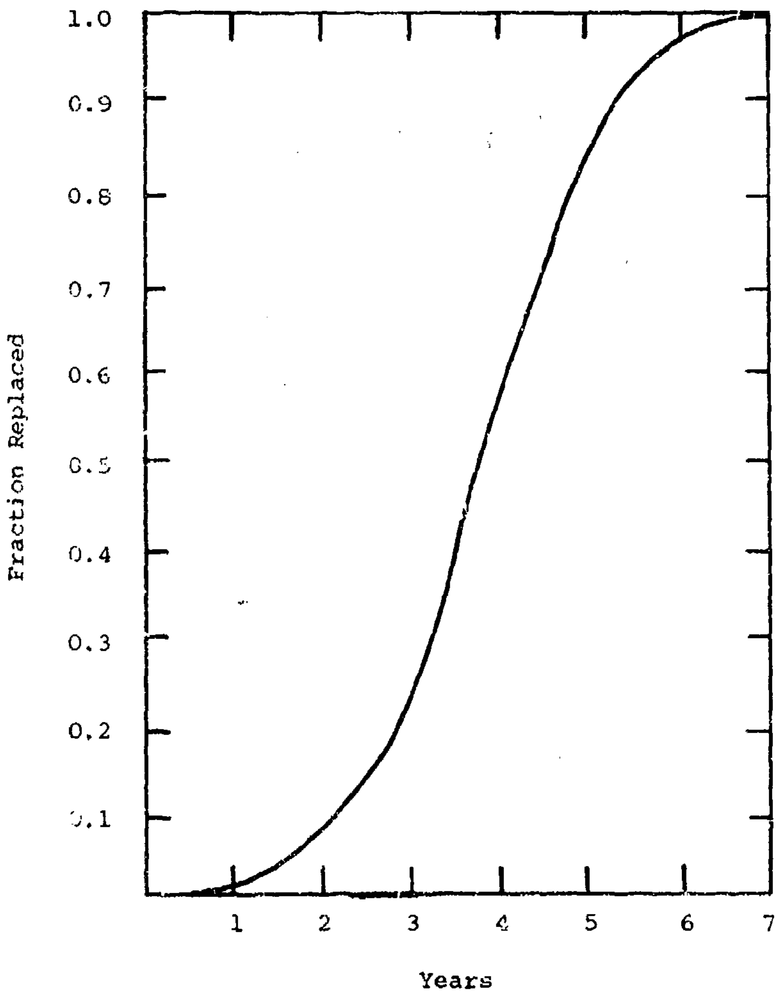

Figure C-2. CUMULATIVE IMPELLER REPLACEMENTS VS TIME FOR AUXILIARY CIRCULATING PUMP (APL 016120387)

APPENDIX D

DEVELOPMENT OF OVERHAUL INTERVAL FOR AUXILIARY CIRCULATING PUMPS

The time-to-replacement distribution of auxiliary circulating pump impellers was developed in Appendix C. As noted in Section 3.4.3, it is probable that impeller replacement took place before impeller erosion was severe enough to cause pump failure. Therefore, the replacement data are considered conservative and the most straightforward way of making them more realistic is to assume that the failure distribution has the same increasing rate as the observed impeller-replacement probability distribution, but failures occur at a fixed period later than the observed replacement. The following discussion illustrates this procedure and reports the results of this operation.

This operation can be most clearly seen by referring to Figure D-1, which illustrates the cumulative failure distribution times shown in Figure C-1 (Appendix C) and tabulated in Table 3-6 (Section 3.4.3). Figure D-1 also shows two failure distributions with the same shape but offset from the tabulated distribution by one and two years. This operation is presented in tabular form in Table D-1.

From Table D-1, it can be seen that overhaul intervals of three, four, and five years are feasible. Intervals shorter than three years would result in few failures (less than 20 percent) before pump overhaul, even for a minimal lag between replacement and failure. Intervals longer than five years would allow a substantial proportion of the pumps to fail, even if the lag was as long as two years.

Table D-2 compares the characteristics and risks of intervals of three, four, and five years. It assumes that the lag between observed replacements and failure to perform was between one and two years. A three-year overhaul interval is a very conservative interval, preventing most failures, but having the highest cost, as a result of premature part replacement. Five years is a riskier interval because for it to be viable, the lag must be longer than one year. A four-year interval is in the middle, but it tends to be conservative.

On the basis of the presented data, a five-year interval between impeller replacements was selected. The primary reasons for selecting the five-year interval were that it requires the smallest feasible number of pump openings and the consequences of being wrong are not serious.

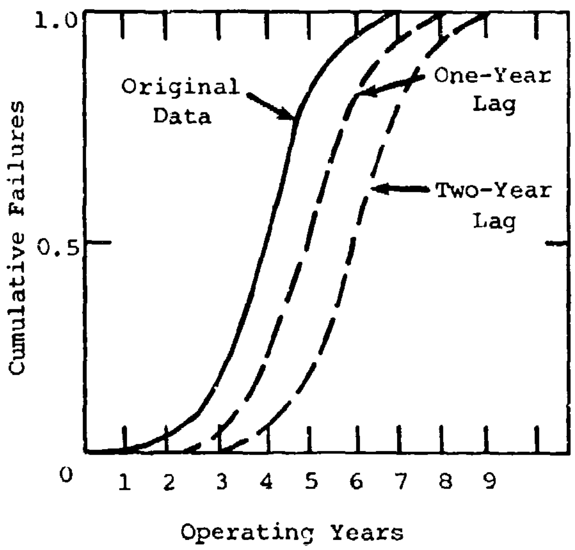

Figure D-1. ASSUMED CUMULATIVE FAILURES FOR AUXILIARY SALT WATER PUMPS BASED ON IMPELLER REPLACEMENT DATA*

*Replacement data given in Appendix C.

Table D-1. ASSUMED CUMULATIVE FAILURES FOR AUXILIARY SALT WATER PUMPS BASED ON IMPELLER REPLACEMENT DATA*

Impeller Replacement Interval (Years)	Assumed Cumulative Percentage of Pump Failures Before Impeller Replacement (By Assumed Time Between Historical Replacement and Actual Failure)		
	0 Years	1 Year	2 Years
1	1	≈0	≈0
2	5	1	≈0
3	22	5	1
4	54	22	5
5	84	54	22
6	98	84	54
7	99	98	84

*Replacement data given in Appendix C.

Table D-2. CONSEQUENCES OF OVERHAULING PUMPS AT THREE-, FOUR-, AND FIVE-YEAR INTERVALS

Overhaul Interval (Years)	Failures Before Overhaul* (Percent)	Risk	Comment
3	1-5**	None.	- Definitely before onset of high failure rate. - Highest cost. - Many components replaced before it is necessary.
4	5-20	Up to 20 percent of pumps may fail before overhaul.	- Highly likely that overhaul will occur before onset of high failure rate. - Some components will be replaced before it is necessary.
5	20-50	A substantial proportion of pumps may fail before overhaul.	- Pumps could operate in the time frame of a high failure rate. - Lowest cost. - Consequences of failure are not serious.

*From Table D-1; percentages are rounded.
**Indicates that if the lag between impeller replacement and failure was one year, 5 percent of the impellers would fail before overhaul and if the lag was two years 1 percent would fail.

APPENDIX E

MRC EVALUATION

The DDEOC MRC Evaluation form in this appendix specifies the Maintenance Index Pages (MIPs) applicable to the Salt Water Circulating Water System and lists the Maintenance Requirements Cards (MRCs) that should be modified or deleted and indicates where new MRCs are needed:

- MRC Title - Description of maintenance specified by MRC
- MRC Number - Identification number of MRC
- Responsibility - Organizations responsible for change (if any)
- Current Status (self-explanatory)
- Man-Hours - Personnel time burden allotted to complete maintenance action
- Frequency - When the MRC maintenance action is to be performed, e.g., D = Daily, W = Weekly, M = Monthly, Q = Quarterly, S = Semi-annually, A = Annually, C = Once Every Cycle, R = As Required
- Type - Perform maintenance (P), or survey material condition of components (S)
- Who Performs Test - Maintenance action or test to be performed by tender, or DDEOC site team, or Ship's Force personnel
- Where Performed - (self-explanatory)
- Data - Indicates whether data are recorded during performance of maintenance action

DDEOC MRC EV

MRC TITLE	MRC NUMBER	RESPONSIBILITY		CURRENT STATUS			MAN-HOURS		
		NAVSEA	DDEOC	OLD WITH NO CHANGE	OLD WITH REVISION	NEW	PRE DDEOC M/H	POST-DDEOC M/H	PRE
Main Circulating Pump, MIP E-5/59-A6									
Back-Flush Lube Oil Cooler	94 E87F N	X			X		2.0	2.0	
Inspect Pump Internal Parts	66 K32G N	X			X		36.0	36.0	
Inspect carbon packing Inspect turbine exterior	65 H16V N	X			X		6.0	6.0	
Inspect Reduction Gear	65 H16W N	X			X		0.5	0.5	
Auxiliary Condenser Salt Water Circulating Pump, MIP E-017/296-21									
Inspect Internal Parts	21 A14V A	X			X		7.0	7.0	

*P · PERFORM MAINTENANCE; S = SURVEY INSPECTION

SHIP CLASS: DDG-37

SMA NO: 37-106-256

SYSTEM: Salt Water Circulating System

DEOC MRC EVALUATION

MAN-HOURS		FREQUENCY		TYPE*	WHO PERFORMS TEST			WHERE PERFORMED	DATA	REMARKS
PRE-ODEOC M/H	POST-ODEOC M/H	PRE-ODEOC	POST-ODEOC	P-PERF. S-SURV.	TENDER	ODEOC	SHIP	I-IN PORT S-AT SEA	YES NO	
2.0	2.0	M	Q	P			X	I	No	Changing the frequency of this task from "monthly" to "quarterly" will result in a significant reduction in man-hours with little degradation in performance or material condition.
36.0	36.0	C	C	S			X	I	No	Add a note the MIP to perform this action prior to overhaul.
6.0	6.0	C	36M	S			X	I	No	The frequency of this task is changed from "cyclical" to "36M" so that the frequency of performance remains unchanged during an extended operating cycle.
0.5	0.5	C	36M	S			X	I	No	Add a note that reduction gear maintenance should be accomplished by an industrial activity. The frequency of this action is changed from "cyclical" to "36M" so that the frequency of performance remains unchanged during an extended operating cycle.
7.0	7.0	A	R	S			X	I,S	No	This action is deleted and replaced with a recommendation to overhaul these pumps at five-year intervals.

APPENDIX F

DDEOC ACTION TABLE

DDEOC action items are presented in the table of this appendix. The table is formatted to provide the implementation status of changes through completion of the Class Maintenance Plan and to serve as a ready reference to specific sections in Chapter Three that address in detail the problems involved.

DDEOC ACTION TA

1 ACTION ITEM * a NO.	b TITLE	2 DDEOC EVALUATION **	3 ACTION ITEM DESCRIPTION	4 REPORT REFERENCE (PARA.)	5
1.	Baseline Overhaul Requirements				
	Main Circulating Pump Turbine		Class "B" Overhaul the turbine in accordance with TRS 0256-086-602.	3.2	
	Main Circulating Pump		Overhaul only if POT&I or CSMP proves it to be necessary.	3.3	
	Auxiliary Circulating Pump		Class "B" Overhaul the pump in accordance with TRS 0256-086-600 or TRS 0256-086-619.	3.4	
	Auxiliary Circulating Pump Motor		Overhaul only if POT&I or the ship's CSMP proves it to be necessary.	3.5	
	Auxiliary Circulating Pump Motor Controller		Overhaul only if POT&I or the ship's CSMP proves it to be necessary.	3.5	
	Expansion Joints		Replace only if over five years old or if inspection shows replacement to be necessary.	3.8	
2.	Intra-Cycle Maintenance Requirements				
	Auxiliary Circulating Pump		Overhaul at five-year intervals	3.4	
3.	Follow-On ROH Requirements				
	Main Circulating Pump Turbine		Overhaul as shown to be necessary by POT&I or the ship's CSMP.	3.2	
	Main Circulating Pump		Repair or overhaul as shown to be necessary by POT&I or the ship's CSMP.	3.3	
4.	Reliability and Maintainability Improvements				
	Auxiliary Circulating Pump		Overhaul at five-year intervals.	3.4	
	Duplex Strainer		Develop a ShipAlt to replace the present strainer with an appropriately sized strainer.	3.6	

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTINUATI

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY – ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

SHIP CLASS: DDG-37

SMA NO: 37-106-256

SYSTEM: Salt Water Circulating System

ʼOC ACTION TABLE

4 REPORT REFERENCE (PARA.)	5 RESPONSIBILITY †	6 SCHEDULING DATES			7 REMARKS, FUNDING IMPLICATIONS, ETC.	8 ACTUAL ACTION TAKEN
		a REQD.	b START	c COMP.		
3.2	NAVSEA 934					
3.3	NAVSEA 934					
3.4	NAVSEA 934					
3.5	NAVSEA 934					
3.5	NAVSEA 934					
3.8	NAVSEA 934					
3.4	NAVSEA 934					
3.2	NAVSEA 934					
3.3	NAVSEA 934					
3.4	NAVSEA 934/ NAVSEC					
3.6	NAVSEA 934/ NAVSEC					

FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

DDEOC ACTIO

1 ACTION ITEM* a NO.	b TITLE	2 DDEOC EVALUATION**	3 ACTION ITEM DESCRIPTION	4 REPORT REFERENCE (PARA.)
5.	Planned Maintenance System Changes			
	Main Circulating Pump		Change the periodicity of MRC 94 E87F N from monthly to quarterly and MRC 65-H16V N and MRC 65 H16W N from cyclic to 36 months. Add a note to perform MRC 66 K32G N prior to overhaul. All are on MIP E-5/59-A6.	3.2
			Add a note that reduction gear maintenance should be performed by an industrial activity.	3.2
	Auxiliary Circulating Pump		Delete MRC 21 A14V A on MIP E-017/296-2.	3.4
6.	Industrial Facility Improvements		None.	
7.	IMA Improvements		None.	
8.	Integrated Logistics Support (ILS) Requirements			
	Centrifugal Pumps & Motors		Provide Ship's Force with a suitable Centrifugal Pump Repair Manual.††	3.4 3.5
			Provide suitable ball bearing heater ovens.††	3.5

* NOTE 1: DEVELOPING ACTIVITY FILL IN THE FOLLOWING BLOCKS: 1a, b; 3; 4; 5 (IF KNOWN); 6a, IF REQUIRED FOR CONTIN

** NOTE 2: DDEOC EVALUATION – APPROVED, FURTHER STUDY REQ'D, ETC.

† NOTE 3: RESPONSIBILITY -- ACTIVITY RESPONSIBLE FOR TAKING THE ACTION.

†† NOTE 4: THESE RECOMMENDATIONS WERE MADE IN THE DDG-37 CLASS FIREMAIN AND AUXILIARY MACHINERY COOLING

SHIP CLASS: DDG-37

SMA NO: 37-106-256

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DDEOC ACTION TABLE

	4 REPORT REFERENCE (PARA.)	5 RESPONSIBILITY †	6 SCHEDULING DATES a REQD.	b START	c COMP.	7 REMARKS, FUNDING IMPLICATIONS, ETC.	8 ACTUAL ACTION TAKEN
F N - to C e on.	3.2	NAVSEA 04					
e- s-	3.2	NAVSEA 04					
6-2.	3.4	NAVSEA 04					
	3.4 3.5	NAVSEA 934/ NAVSEC					
	3.5	NAVSEA 934/ NAVSEC					

RED FOR CONTINUATION OF DEVELOPING ACTIVITY TASK; 7, AS NECESSARY.

NERY COOLING WATER SMA, SMA 37-201-521.